PLANT COMMUNITY VARIABILITY ON A SMALL AREA IN SOUTHEASTERN MONTANA

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Abstract.— Plant communities are inherently variable due to a number of environmental and biological forces. Canopy cover and aboveground biomass were determined for understory vegetation in plant communities of a prairie grassland—forest ecotone in southeastern Montana. Vegetation units were described using polar ordination and stepwise discriminant analysis. Nine of a total of 88 plant species encountered and cover of litter were the most useful variables in distinguishing among vegetation units on the study area and accounted for nearly 100 percent of the variation in the data. Seven vegetation units were different ($P < 0.05$) after all 10 variables had been entered into the analysis. Some plant communities were represented by two or three different vegetation units, indicating that some plant communities were variable and nonuniform in botanical composition over a relatively small area. This variability will influence management practices for these areas. Multiple-use management will benefit by recognition of inherent plant community variation.

Mueller-Dombois and Ellenberg (1972) defined plant communities as concrete definable units of vegetation that can be recognized and are obvious to the eye. Plant communities are often named after species that contribute to their unique structure or composition, or they are named after a unique environmental condition. Some examples from southeastern Montana include sagebrush-grassland, pine forest, and riparian communities. However, plant communities are variable and can be a mosaic of finer units of vegetation. Poore (1955) termed these vegetation abstractions *noda*, and they are presumably analagous to Whittaker's (1967) ecological groups.

The variability within plant communities at any time is due to a number of environmental and biological forces. Environmental influences include the geology of an area, soil communities, climate, solar radiation, and fire. Biological influences can be soil microbes, grazing animals, intra- and interspecific competition, genetics, successional patterns, and evolution. These forces create a dynamic process of vegetation patterning. Within a person's lifetime, however, plant communities are relatively stable, barring catastrophic events.

Variations within plant communities have long been recognized. Gleason (1926) stated that no two plant communities are exactly alike even though they contain the same species. Whittaker (1970) noted that plant communities are often less than discrete units, with no absolute boundaries among communities. Other plant ecologists have come to similar conclusions (Curtis and McIntosh 1950, Cottam 1949, Goodall 1953). Mueller-Dombois and Ellenberg (1972), however, suggested that plant communities can be individualists as well as continua. One aspect of current vegetaton ecology is the study of community variability and how that relates to the consequences of land management and the effects of human technology.

Plant community variability can create problems for land managers regardless of the source of variability. Successful management of vegetation for livestock grazing, wildlife habitat, water yield, soil conservation, etc., requires knowledge of plant community variability. Different vegetation units will not respond similarly to management. Practices recommended for one situation may be unsuccessful in another, even though the plant community appears to be the same. Many hectares of native rangeland are being manipulated primarily to increase the number of livestock supported, while still maintaining a viable ecosystem.

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Much rangeland in the western United States, including southeastern Montana, is without acceptably published information on vegetation characteristics. We believe that recent quantitative practices in plant ecology can and should be applied to management problems at the local level.

The purposes of this paper are (1) to present a method of assessing plant community variation, (2) to illustrate the variability within plant communities on a small study site, and (3) to identify potential consequences of plant community variation for management practices.

Study Area and Methods

The study was conducted on about 11,300 ha of rangelands along the northern edge of the Black Hills in southeastern Montana. The study area was immediately west of Alzada, Carter County. Elevation ranged from 1036 to 1128 m and average annual precipitation is approximately 37 cm.

Soils included alluvial clayey deposits in bottom areas and shale at higher elevations. Surface deposits of bentonite clay were numerous. Bentonic soils are characterized by a shallow A horizon and are saline or sodic (Bjugstad et al. 1981).

Most of the area was in private ownership and grazed by both sheep and cattle on a rest rotation system. Mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), and pronghorn (*Antilocapra americana*) were present on the study area.

Southeastern Montana is classified as a wheatgrass-needlegrass (*Agropyron-Stipa*) prairie by Küchler (1964). Garrison et al. (1977) classified the study area as plains grassland with ponderosa pine (*Pinus ponderosa*) forest. Plant names follow those given by Scott and Wasser (1980).

Four plant communities were recognized on the study area. A sagebrush-grassland community occupied a majority of the area. This community was dominated by big sagebrush (*Artemisia tridentata*) and buffalo grass (*Buchloe dactyloides*). A riparian community, primarily wooded stream bottoms, was the next most abundant plant community. Major plants there were boxelder maple (*Acer negundo*) and snowberry (*Symphoricarpos* spp.). A pine forest community existed at higher elevations, consisting of ponderosa pine and western wheatgrass (*Agropyron smithii*). Isolated portions of the study area were open grassland. The most abundant plants there were western wheatgrass and needleleaf sedge (*Carex eleocharis*). These subjective classifications were made to facilitate design of an adequate sampling scheme.

Four sample sites were selected in both the sagebrush and riparian communities. Two sample sites were studied in the pine forest and two in the grassland community. These sites were judged to be representative of their respective plant communities, and encompassed the range of perceived variability within these communities. The number of sampling sites established in each plant community was based on the total area occupied by that community, and/or the observed variability within each community.

Canopy cover and aboveground biomass of plant species were estimated in each sampling site during summers of 1979 and 1980. Three parallel 50-m line transects were systematically established approximately 30.5 m apart at each site. Canopy cover was measured using 50 plots (2×5 dm) systematically spaced at 1-m intervals along each transect (Daubenmire 1959). Six hundred plots were observed in both riparian and sagebrush areas and 300 in grassland and pine forest communities each year of the study. We assessed the adequacy of our sample size using the formula presented by Johnson and Laycock (1972), with a degree of precision needed to estimate plant species within 15 percent of their mean with 95 percent confidence.

Aboveground biomass at peak growth was estimated by clipping 20 plots at 5-m intervals along two of the transect lines at each site. All plants, excluding shrubs, were clipped at ground level, air dried for two weeks, oven dried at 60 C for 24 hours, then weighed to the nearest one-tenth gram.

Individual transects of each year were grouped into similar vegetation units using multidimensional polar ordination (Bray and Curtis 1957), as described by Mueller-Dombois and Ellenberg (1974). Ordination axes endpoints were chosen using guidelines and criteria suggested by Mueller-Dombois

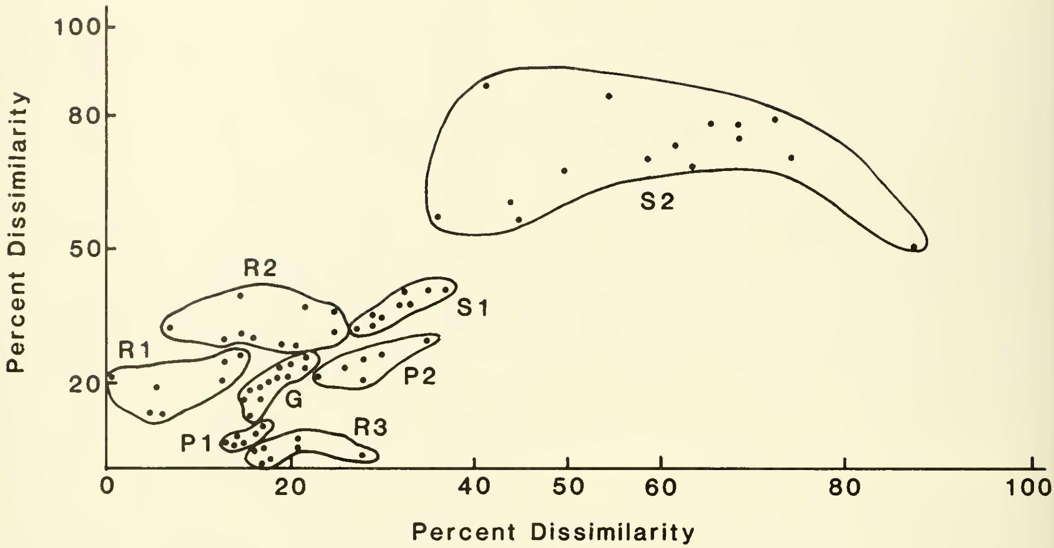

Fig. 1. Location of vegetation transects along ordination axes and grouping of transects into vegetation groups. R = riparian, P = pine forest, G = grassland, and S = sagebrush.

and Ellenberg (1974) and Newsome and Dix (1968). For this analysis transects were ordinated based on canopy cover estimates. Such an approach provided for the assessment of variability among transects and sampling sites within a plant community. Gauch et al. (1977) found that polar ordination was subject to less distortion than other ordination procedures when sampling is clustered and outlier samples are included.

The vegetation groups were then analyzed with stepwise discriminant analysis for three reasons (Cooley and Lohnes 1962, Klebenow 1969, Klecka 1975). Since polar ordination is somewhat subjective and based on sample similarities with axes endpoints, some vegetation groups may be erroneous. Most clustering techniques do in fact derive nonsignificant groups (Strauss 1982). Discriminant analysis maximizes differences among groups and was used to determine if vegetation groups were significantly different from one another. Green (1980) suggested that multivariate tests were so powerful in detecting differences that a nonsignificant result may be more meaningful than a significant result. Discriminant analysis also selects the set of variables (plant species) that are the most useful in differentiating among groups. This property is desirable in that many plant species are encountered that added little to explaining variation within and among plant communities. Discriminant analysis also generates classification functions from the most useful variables. These functions can be used to determine the vegetation groups to which nonsignificant groups were most similar. The classification functions could also be used to assign samples from future surveys to the vegetation group they most nearly resemble (MacCracken and Hansen 1982).

Aboveground biomass was analyzed by testing for differences between vegetation units (as determined by ordination and discriminant analysis), categories (grasses and forbs), and years, using a three-way analysis of variance test followed by Duncan's new multiple range test. Differences were considered significant at $\alpha = 0.05$.

RESULTS

The number of plots needed to estimate canopy cover of plants with the degree of precision stated was 1025 and 1098 in 1979 and 1980, respectively. Our observation of 1800 plots per year was more than adequate.

Ordination arranged the 72 transects in such a manner that eight groups could be delineated based on the proximity of transects from similar sample sites (Fig. 1). Sagebrush and pine communities were each represented by two groups, riparian communities by three, and the grassland community by one. Discriminant analysis indicated that the two sagebrush groups were not distinct (P > 0.05). As a result, both sagebrush groups were combined for final analysis, resulting in seven groups defined at this point as seven vegetation units.

Eighty-eight plant species were encountered along the transects; of these, 9 plant species and percent cover of litter were the most useful variables in discriminating between vegetation units and accounted for nearly 100 percent of data variation (Table 1). Those discriminating variables, in order of significance, were smooth brome (*Bromus inermis*), litter, starry cerastium (*Cerastium arvense*), Rocky Mountain juniper (*Juniperus scopulorum*), snowberry (*Symphoricarpos* spp.), red threeawn (*Aristida longiseta*), big

Table 1. Mean percent canopy cover of plant species, bare ground, and litter of seven vegetation units in southeastern Montana. Estimates were taken during summers 1979 and 1980.

	Vegetation units						
	Riparian			Grassland	Pine		Sagebrush
Categories	1	2	3		1	2	
Bare ground	8	8	4	23	16	8	20
Litter +	29	22	44	28	53	48	15
Total cover	64	81	67	41	16	44	64
Grasses							
Agropyron smithii +	2	16	3	16	4	3	7
Agropyron spp.	10	8			°	°	°
Aristida longiseta +					1	°	
Bouteloua gracilis				1	4	2	1
Bromus inermis +		°	59				
B. japonicus	°	°	°	1	°	1	°
B. tectorum	2	°			1		°
Buchloe dactyloides				°	1	3	20
Carex spp.		3	°	5	3	14	5
Calamovilfa longifolia	°			1	1	°	2
Elymus macounii	°	5					
Hordeum jubatum	°	3	°				
Koeleria cristata		°		°	°	1	2
Muhlenbergia richardsonus	°						
Panicum capillare		°					
Phleum pratense	°	8					
Poa spp.	21	14	1	°	°	°	°
Schedonnardus paniculatus				°		°	°
Stipa viridula		°		°		°	1
Unidentified		3					
Forbs							
Achillea millefolium	°	°	1	°	1	2	1
Cerastium arvense +					°	2	
Geum aleppicum		°					
Lactuca serriola	1	°					
Plantago spinulosa				1	°	°	°
Rumex crispus	1	1					
Sphaeralcea coccinea				°			
Taraxicum officinale	1	5	1	°	°	°	°
Thlaspi arvense	°	°		°			
Vicia americana			°				°
Shrubs							
Artemisia tridentata +				1	°	1	11
Juniperus scopulorum +					2	1	
Opuntia polycantha +				4	°	1	2
Phlox hoodii				°		°	2
Sarcobatus vermiculatus	°						°
Symphoricarpos spp. +	27	17	1				
Rosa spp. +	1	5		1			°

°<1

+ Indicates plant species and variables most useful in discriminating between the seven vegetation units.

sagebrush, western wheatgrass, rose (*Rosa* spp.), and plains prickly pear (*Opuntia polyacantha*). Smooth brome, litter, and starry cerastium alone accounted for 94 percent of data variation. However, the remaining seven variables contributed significantly to the separation of vegetation units. Discriminant function classification coefficients ranged from –0.01 to 56.42 (Table 2).

Differences among the seven vegetation units ($P < 0.05$) arose as each variable was entered into discriminant analysis. These differences changed slightly as each variable was considered, but the seven units were distinct ($P < 0.05$) after all 10 variables had been considered. Transects from each site combined into the same vegetation unit for each year, indicating that differences in plant canopy cover were not significant between years. Generally, transects from one or more sampling sites combined to produce a vegetation unit. Nevertheless, there was some mixing of transects from the four riparian sites sampled among the three Riparian vegetation units.

Differences were detected in aboveground biomass among units and plant taxa (Table 3). The Riparian 3 unit had more grass ($P < 0.01$) than the Riparian 1 and 2 units, sagebrush, grassland, and both pine units. Grass biomass was also greater ($P < 0.01$) in the Riparian 2 unit, sagebrush and grassland units than in both pine forest units. Still, forb biomass between units was similar ($P > 0.05$). Grass biomass was higher than forb biomass ($P < 0.01$) in all riparian units. Grass and forb biomass in other units were similar ($P > 0.05$). No year differences were observed for total biomass ($P > 0.05$) for any vegetation unit or category. Some plant species were common to all units, but others were indicative of a particular vegetation unit. Western wheatgrass was most abundant in the Grassland and Riparian 2 units. Red threeawn and starry cerastium were confined to pine forest areas. Smooth brome and snowberry occurred exclusively in riparian units, as did combined wheatgrasses. Common tumblegrass (*Shedonnardis paniculatus*), and plains prickly pear were useful in distinguishing the grassland unit, and big sagebrush was dominant in the sagebrush unit.

DISCUSSION

Vegetation units as defined in this study represent areas that are the most similar in vegetative composition. Variation inherent in sampling methods has been reduced to a minimum by the quantitative techniques used, and accurately describes these vegetation units at a refined level. The methods used illustrate the variation from site to site within some plant communities. Discriminant analysis indicated that relatively few plant species accounted for the majority of variation attributable to differences in plant cover among the vegetation units.

TABLE 2. Discriminant function coefficients for the 10 variables most useful in distinguishing between vegetation units in southeastern Montana.

	Vegetation units						
	Riparian			Grassland	Pine		Sagebrush
Variables	1	2	3		1	2	
Litter	1.63	0.92	1.19	1.34	4.42	4.49	0.82
Constant	–32.87	–28.74	–57.49	–22.11	–174.09	–185.15	–12.31
GRASSES							
Agropyron smithii	0.08	0.97	–0.31	0.09	–1.01	–1.03	–0.04
Aristida longiseta	15.39	7.47	11.84	12.61	56.42	46.68	8.13
Bromus inermis	–0.66	–0.43	1.01	–0.54	–1.71	–1.74	–0.32
FORBS							
Cerastium arvense	12.89	6.88	9.66	10.73	34.38	49.26	6.06
SHRUBS							
Artemisia tridentata	0.19	0.14	0.13	–0.01	0.48	0.51	0.88
Juniperus scopulorum	11.86	6.49	8.82	9.89	36.15	33.83	6.00
Rosa spp.	0.01	1.39	–0.50	–0.06	–1.72	–1.76	–0.16
Symphoricarpos spp.	0.53	0.61	–0.04	0.07	–0.12	–0.12	0.01
Opuntia polyacantha	–1.54	–2.55	–0.44	0.17	–1.81	–1.94	–0.53

Polar ordination arranged transects along a moisture gradient for both axes. Vegetation units representing areas of high soil moisture (based on plant species presence) fell into the bottom left quadrant and xeric vegetation units fell into the upper right quadrant (Fig. 1). Many studies have shown strong correlations between plant community composition and soil moisture regimes in the western United States (Dahl 1963, Galbraith 1971, Marks and Harcombe 1981, Monk 1960, Marks and Harcombe 1975, Harniss and West 1973). Marks and Harcombe (1981) interpreted an ordination axis as representing a soil moisture gradient even through they did not measure soil moisture directly.

Some plant communities in southeastern Montana are relatively homogenous. The sagebrush-grass and grassland communities were not different in plant cover among the sites sampled within each type. We did subjectively divide the sagebrush-grass transects into two groups based on ordination results; however, discriminant analysis did not detect any differences ($P > 0.05$) in plant cover among the two groups. Polar ordination when used as a clustering technique can produce nonsignificant groups. Current studies in plant community classification often use an ordination or clustering technique to define plant community types (Marks and Harcombe 1981, Thilenius 1972, Severson and Thilenius 1976). Rarely are the groups that result from these techniques tested for significance (Strauss 1982).

Riparian and pine forest communities are relatively heterogenous in southeastern Montana. The variation and factors producing dif-

Table 3. Mean kilograms per hectare of grasses and forbs occurring in seven vegetation units in southeastern Montana. Estimates were taken during summers of 1979 and 1980.

	Vegetation units						
	Riparian			Grassland	Pine		Sagebrush
Plant species	1	2	3		1	2	
Grasses							
Agropyron smithii	75	192	11	222	48	59	125
Agropyron spp.	24	°			5	4	6
Aristida longiseta					6	°	
Bouteloua gracilis				6	30	21	14
Bromus inermis		109	5998				
B. japonicus	5	1		1		2	2
B. tectorum					8	4	3
Buchloe dactyloides				1	5	17	115
Carex spp.		14					66
Calamovilfa longifolia				7			86
Elymus macounii	13	22	°				
Hordeum jubatum		25					
Koeleria cristata				1		3	12
Muhlenbergia richardsonus	°						
Panicum capillare		°					
Phleum pratense		137					
Poa spp.	263	179	3	3		1	3
Schedonnardus paniculatus				5		°	2
Stipa viridula		2		2		6	29
Others		50					
Total Grass	106	156	802	78	30	36	86
Forbs							
Achillea millefolium	7	°	1	1	2	20	10
Cerastium arvense					°	18	
Geum aleppicum		°					
Lactuca serriola	20	22					
Plantago spinulosa				3	°	1	
Rumex crispus	21	7					
Sphaeralcea coccinea				1			2
Taraxicum officinale	6	25	1	3		2	3
Thlaspi arvense	3	7					
Vicia americana		°	°				°
Total Forb	10	20	11	5	5	9	16

°<1

ferences among sites in riparian and pine forest communities are recognizable and interpretable. For example, riparian communities (i.e., hardwood forests along stream bottoms) were divided into three distinct vegetation units in this study (Table 1 and 3, Fig. 1). In general, hardwood forests, occurring as woody draws and stringer woodlands, are declining on the northern Great Plains (Boldt et al. 1978). Declining woodlands are represented by trees of old age, decadence, and advanced stages of breakup. Reproduction is poor and ground cover is primarily herbaceous. In contrast, "healthy" woody draws are characterized by thrifty, moderately dense stands of trees, and a vigorous shrub understory (Boldt et al. 1978). The Riparian 1 unit was representative of a healthy area. Shrub cover averaged 27 percent, and herbaceous vegetative growth averaged approximately 117 kg/ha. The Riparian 3 unit represented a declining woodland. Shrub cover averaged 1 percent, and herbaceous growth averaged 817 kg/ha, primarily because of the invasion of smooth brome from nearby hay meadows. The decline of hardwood forests on the northern Great Plains has been attributed to a number of environmental and biological factors (Boldt et al. 1978).

Two vegetation units were recognized in the pine forest community. These units are more easily interpreted than those of riparian sites. The Pine 1 unit had a relatively dense stand of trees (Table 4). Understory cover and aboveground biomass were lower than in the Pine 2 unit, but percent ground litter was higher in this unit. The Pine 2 unit had a relatively more open stand of trees, with greater growth of understory vegetation and less ground litter. The difference in tree density between the two units was perhaps due to moisture regimes as related to aspect of the sites.

Management Implications

Results of this study show that some plant communities in southeastern Montana are variable in botanical composition, being composed of distinct and differing vegetation units. This variability can be attributed to a number of environmental or biological factors. Different vegetation units within a plant community will respond differently to management practices. This site-specific variability, once recognized, will influence management decisions. For example, consider an area of riparian community in southeastern Montana in which a rancher wishes to convert part to hay meadows. If all three Riparian units were present, the decadent woodland would probably be most easily converted. The healthy woodland would be valuable as wildlife habitat, to trap winter snows to fill stock ponds downstream, and as shading areas for livestock. The Riparian 2 unit, an intermediate unit between healthy and decadent stands, could be slated for improvement toward a healthy stand. Boldt et al. (1979) presented treatments aimed at improving decadent woodlands on the northern Great Plains. The Pine 1 unit could be thinned to increase forage production for livestock, water yield, and timber production.

By simply recognizing the inherent variability in plant communities, a number of management options became apparent. On federal lands, where multiple use management is law, this approach should be readily utilizable.

TABLE 4. Density (no/ha) of trees in pine and riparian vegetation units in southeastern Montana.

	Vegetation units				
	Pine		Riparian		
Tree	1	2	1	2	3
Pinus ponderosa	172	20			
Quercus macrocarpa	192	52			
Juniperus scopulorum	88	184			
Fraxinus pennsylvanicas			600	976	872
Acer negundo			524	496	260
Prunus virginiana					352
Salix amygdaloides			5		
Total	452	256	1144	1472	1484

Recognition of some vegetation units defined in this study may not be easy, especially the Riparian 2 unit. However, discriminant classification functions can be used for that purpose. Using estimates of mean percent canopy cover of discriminator species multiplied by discriminant function coefficients (Table 2), a composite score can be derived by adding the products for any sample. The function producing the largest score indicates the vegetation unit from which the sample came. Since only ground litter and nine plant species were important in distinguishing among the vegetation units on the study area, only these variables need be measured in future surveys (MacCracken and Hansen 1982). This should greatly reduce field effort and associated costs. The application of these classification functions beyond the immediate study area is questionable. However, they may be suitable for portions of southeastern Montana where the same plant communities occur and environmental and biological forces similar to those at work here operate.

Ideally, each vegetation unit defined in this study should be managed on an individual basis, using practices known to benefit those units whether management be for livestock, wildlife, water, or minerals. This would require intensive management to achieve desired results. Nevertheless, it is possible to classify existing areas based on unit dominance and manage for that unit.

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